Studies in Agricultural
Capital and Technology

Economics and Sociology
Ocassional Paper No. 171

A STUDY OF ALLOCATIVE EFFICIENCY AT THE FARM LEVEL IN SOUTHERN BRAZIL

By

Jose F. Noronha

December 1973

Department of Agricultural Economics and Rural Sociology
The Ohio State University
2120 Fyffe Road
Columbus, Ohio 43210

A STUDY OF ALLOCATIVE EFFICIENCY AT

THE FARM LEVEL IN SOUTHERN BRAZIL

By

José F. Noronha

Abaeté, M.G., Brazil

Director: Dr. Fred E. Justus, Jr., Professor of Agricultural Economics

Lexington, Kentucky

1973

TABLE OF CONTENTS

A STUDY OF ALLOCATIVE EFFICIENCY AT THE FARM LEVEL IN SOUTHERN BRAZIL*

Introduction

Brazil has had surprisingly high rates of economic growth in recent years, both in the industrial and the agricultural sectors (Baer, 1972). The industrial sector's growth is supported by governmental policies intended to protect and modernize the domestic industry and hence increase capital formation. Inflow of foreign capital as well as technological changes and export incentives play a very important role in this process (Baklanoff, 1970, p. 198). On the other hand, agricultural output grows almost entirely by increasing cultivated area, except for some effort to increase productivity in the Central-South region.

Since income per capita is increasing, demand for agricultural products is rising. Furthermore, (a) a very large proportion of the brazilian population still depends on the agricultural sector, (b) agriculture is characterized by traditional methods of production and low productivity levels, and (c) both population and urbanization are increasing at high rates. Therefore, substantial increase in productivity in agriculture is necessary to meet domestic consumption needs and continue to support the process of development.

---

*This paper is based on the author's Ph.D. Dissertation at the University of Kentucky, 1973. It is the result of a cooperative effort between the Department of Agricultural Economics of the University of Kentucky and the Department of Agricultural Economics and Rural Sociology of The Ohio State University.

Recent policies providing incentives for exports of agricultural products add to the burden imposed on the agricultural sector. These policies favor more diversified exports and likely will have a major impact on reallocation of resources at the farm level. Under full employment, increases in agricultural production would have to take place through shifts outward in the agricultural production possibility curve. However, full employment is not the case, so production can increase by either (or both) moving along the existing production functions, or shifting them upward via technological changes. Adams (1970, p. 20) predicted that "A major part of future agricultural growth will likely be determined by creating and adapting, through research, new technologies appropriate for Brazil."

Moving along the production function surface, toward or away from the point of maximum economic efficiency, is the subject of allocative efficiency. Thus, it becomes important to identify and estimate production function in order to assess how well producers have been allocating their resources to achieve the assumed goal of individual profit maximization.

Several levels of aggregation can be considered in estimating production functions, from the farm-level micro studies to the macro-models of the whole sector. The present study is the first type, attempting to estimate production functions for different farm types. It is a study of the production unit in isolation. Yet, the complex interrelations between production and consumption decisions inherent to the farm business is recognized.

Objectives

The general objective is to identify and analyze differences in resource productivities at the farm level in Southern Brazil. Such a study should shed some light on questions of resource allocation and capital formation in the agricultural sector.

Specific objectives are: (1) To determine possible differences between production functions of three different types of farms in the region (beef cattle, mechanized wheat farms and "mixed" farms); (2) To determine differences in productivity levels, as measured by the production function estimates, as a means to appraise resource allocative efficiency; (3) To determine possible effects of the current price policy on the pattern of resource use in the region and the potential for capital formation at the farm level. It is also hoped that the current dynamic move away from beef cattle and toward wheat production in this region can be at least partially evaluated by this analysis.

Theoretical Models

Production function analysis is the basic economic model used in this study. At the theoretical level a production function is no more than a useful construct. It asserts that a process takes place in which an inflow of factor services (inputs) is transformed into a outflow of products produced (output).

The theory is a simplification of the real world. It assumes that instantaneous transformation takes place under internal and external constraints. The internal constraints are summarized by "the state of the arts," or the shape and level of the production function. External constraints are dictated by factor and product market conditions. Further simplifications are achieved by assuming perfectly competitive input and output markets as well as perfect foresight. Risks, uncertainties, and technological changes are ignored. This is equivalent to saying that available technology is promptly adopted, and maximum output is obtained from each combination of the limited available resources. Hence, the production function can be represented by a single-valued functional relation between inputs and output.

Theoretically, the entrepreneur has in mind an objective to be attained when a production process is undertaken. The most widely accepted objective is profit maximization.

A necessary condition for profit maximization is that inputs be combined so as to minimize the cost of any level of output produced. That is to say, any increase in production must be obtained along the firm's expansion path. Furthermore, profit will be maximized if, and only if, production is expanded up to the point where marginal cost of production equals output price or marginal revenue.

From the point of view of resource use and allocative efficiency analysis, however, it is more comprehensive to state the above equilibrium conditions in terms of input productivities. It can be easily shown that the best resource allocation within the firm is obtained when (a) for each input employed its marginal value product (MVP) equals its marginal factor cost (MFC); and (b) the input combination must be such that the last dollar's worth of each input is equally productive. Similarly, efficient resource allocation among firms is attained when the marginal value product of a given input is the same for all firms employing that input.

This model serves to explain resource allocation since it is possible to empirically estimate the marginal value products of the inputs using statistical techniques. Given the static nature of this model, the analysis has to be restricted to an equivalently static situation. In spite of this restriction, policy implications can be derived from this model by using comparative static analysis.

The stochastic model used here is a modified form of the Zellner et. al. (1966) model. The principal assumption of this model is that the entrepreneur's objective is to maximize the mathematical expectation of the profit function. This in turn implicitly assumes that there exist two types of error in the process of profit maximization; (a) in the production function itself, and (b) in the decision functions. Errors in the production function are due to factors such as weather, diseases, and machine performance, while errors in the decision functions are attributed to the human agent. Both types of error lead to inefficiencies which will be reflected by the size of the residual term of the model.

The general form of the model used here is:

$$Y = A\, D^{B_1}\, L^{B_2}\, K^{B_3}\, e^{u_o}$$

where Y = flow of output produced; D = land input services; L = labor input services; K = capital input services; A = constant term which reflects the level of the function; B_i, for i = 1, 2, 3, = production coefficients; and e^{u_o} = stochastic term of the model that accounts for both controllable and noncontrollable imperfections in the production process. It is assumed that uo is normally distributed with mean zero and variance σ^2. Hence e^{u_o} has a lognormal distribution.

The most interesting feature of this model is that single equation estimation of the linearized form of the production function, using ordinary least squares (OLS), leads to consistent and unbiased estimators (Zellner _et. al.,_ 1966: 786-790). That is to say, the OLS estimates of the parameters of the Cobb-Douglas function are free from the simultaneity bias between input and output usually present in cross-section studies of production function.[1]

Data Source

The data used for estimating the models constitute only a small part of the information gathered by the Capital Formation Project (CFP) team in 1969-70. The CFP is a research project being carried out by

---

[1]De Janury (1972) has generalized this result. He has proven that under the Zellner _et. al._ maximization of expected profit assumption, "direct estimation of the production function from cross-section data on firms is always free from simultaneous equation bias, whatever the functional form specified."

the Ohio State University's Department of Agricultural Economics and Rural Sociology. The general objective of the CFP is to study capital formation at the farm level, technological changes and agricultural output growth in less developed countries (Rask, 1972).

In the Brazilian part of the project, a large cross-section of farmers was interviewed directly using a detailed questionnaire schedule.[2] The purpose was to obtain a range of primary information wide enough to allow the study of the different aspects of the farm business-household complex.

The basic population studied, in most cases, included the farm-household units located within the geographic area of a municipio. This study focuses upon the municipio of Sao Borja in the State of Rio Grande do Sul. A preliminary report regarding the Sao Borja survey has been published in Portuguese by Souza et. al. (1972)

The Region

Sao Borja city is located about 495 km West of Porto Alegre, the state capital (see map). The municipio of Sao Borja is separated from Argentina by the Uruguay River on the West. The estimated area of the municipio is about 5000 km^2, and the population was about 30,000 people in 1970. More than 60 percent of

---

[2]These data were collected by the Centro de Estudos e Pesquisas Economicas (IEPE) da Universidade Federal do Rio Grande do Sul.

STATES

1 ACRE (AC)
2 ALAGOAS (AL)
3 AMAPA*
4 AMAZONAS (AM)
5 BAHIA (BA)
6 CEARA (CE)
7 ESPIRITO SANTO (ES)
8 FERNANDO DE NORONHA*
9 GOIAS (GO)
10 GUANABARA (GB)
11 MARANHAO (MA)
12 MATO GROSSO (MT)
13 MINAS GERAIS (MG)
14 PARA (PA)
15 PARAIBA (PB)
16 PARANA (PR)
17 PERNAMBUCO (PE)
18 PIAUI (PI)
19 RIO DE JANEIRO (RJ)
20 RIO GRANDE DO NORTE (RN)
21 RIO GRANDE DO SUL (RS)
22 RONDONIA*
23 RORAIMA*
24 SANTA CATARINA (SC)
25 SAO PAULO (SP)
26 SERGIPE (SE)
27 FEDERAL DISTRICT

*These are territories

Figure 1.--Sao Borja, Rio Grande do Sul, Brazil

the people live in the rural area. The topography is gently rolling and adaptable to mechanization.

In 1969 the estimated number of farms in the municipio was 2,015. Most of the area (about 70 percent) is used for livestock production. The main agricultural crops are wheat, rice, flax, corn, soybeans and mandioca. Sao Borja ranks as the leading municipio in wheat production in the country, and has a cattle herd which is the 9th largest in the state. There are more than 200 municipios in the state of Rio Grande do Sul.

Wheat production more than doubled between 1968 and 1970, due to increases in both land devoted to the crop and higher crop yield. Production went up from 47,000 to 110,000 tons due to a 100 percent increase in acreage and about a 15 percent increase in yield. Soybean acreage also has been expanding. The livestock herd is increasing in size, even though there is evidence that increasing acreages of wheat and soybeans have reduced the acreage of pasture land. Therefore, either cattle farmers are using their pasture more intensively, or previously idle land is being used as pasture, or both.

Preliminary data indicate that livestock farms are more traditional than the others. Wheat farms are highly mechanized and essentially market oriented, whereas mixed farming is a transitional phase between livestock and wheat farming. Empirical production function estimates should reflect these differences if they actually exist.

Sampling

The only information available prior to the CFP survey about all the 2,015 farms in Sao Borja was total area (in hectares). A decision was made to use the available list of farms, the research team's observations, and secondary data to sample this population.

The population of interest consisted of 653 farms within the size interval of 100 and 5,000 ha. These farms represented 33 percent of the total number of farms and included 79 percent of the *municipio's* total area.[3] A simple random sample of 130 farmers taken from this population was judged to satisfactory. To compensate for nonrespondents the study team started with a list of 200 farmers to be interviewed. The final number of usable questionnaires obtained, after completion and checks, was 169. The fact that the final sample was larger than planned can only benefit the quality of the estimates.

Computation

In order to attain the specific objectives of this research, the sample was divided into three sub-samples composed of 67 cattle farms, 42 mechanized wheat farms, and 60 mixed farms.

"Cattle farms" were defined as those in which "60 percent or more of the annual income from the sale of crops and livestock

---

[3]Farms with less than 100 ha presented insignificant economic importance, and only 6 are larger than 5,000 ha.

(including livestock products) is from sale of cattle." Mechanized wheat farms were those in which 60 percent or more of the annual sales of crops and livestock is from wheat, and each farm has at least one tractor. "Mixed farms," includes all farms in the sample not classified as either cattle or wheat farms. The 60 percent cutoff point was chosen mainly because it indicates a fairly high degree of specialization and still preserves acceptable sub-sample sizes.

Estimating production functions of each farm type separately allows inferences to be drawn about resource productivity by type of farm and within the total region. As available data did not break down different inputs (and outputs) by enterprise on each farm, it was necessary to consider each farm type as having a single-product production function. Mixed farms can, in one sense, be looked upon as a control group.

This procedure may have theoretical implications if the degree of specialization _per se_ implies different levels of technology. If so, any differences between these farm types must be attributed to the classification procedure, and not to actual differences in resource combination. However, Drummond (1972) studying Brazilian farms found that "The efficiency of the firm in production is not related to the level of diversification as measured by the index used." (p. 145). He also contends that the level of diversification and farm size are not associated "in either a theoretical or empirical framework" (p. 146).

Input Variables

The three classical factors of production have been specified, i.e., land, labor, and capital. The definitions and criteria used here are based on those of the Capital Formation Project (Reichert, 1972). This same reference contains the definitions of the output items.

Land input is measured in terms of the total land operated; not necessarily total land owned (in hectare). Total land operated includes cultivated land, natural pasture, and other land. Cultivated land includes irrigated and non-irrigated crop land, as well as improved pasture land. Natural pasture may have received minor improvements but excludes any land which has been reseeded or actively tilled. "Other land" includes that land which is only indirectly used for Agricultural purposes such as forest areas, irrigation facilities, and building areas.

Labor input is measured by the number of man-equivalents of family and hired labor utilized during the year studied. A man-equivalent is defined as a "standard labor unit" working 300 days per year. A standard labor unit is a male between 18 and 59 years of age. Percentage weights were assigned to workers who did not fall within this age interval.

Capital was divided into two main categories: working assets and operating expenses. Working assets represent the sum of the value of buildings, mechanized equipment, trucks, non-mechanized equipment, production livestock and work livestock. Operating expenses represent the sum of total annual crop, livestock, machinery and general expenses used up in the production process. All these capital items were measured in cruzeiros. The value of land is not included in the capital input as it was measured as a separate input (in hectares).

From Stock to Flow Variables

Inputs and output are usually specified in terms of flows during a production period, in this case, the agricultural year of July 1, 1969 to June 30, 1970. All data refer to this annual length of time. However, not all input variables can be measured in flow terms directly. Some input data are available only in terms of their stock value at the time of the interview. Specifically these are the so-called working assets, which have productive life spans of a number of production periods. Therefore, the question of transforming stock values into flows must be considered.

Measuring the annual contribution of working assets to the production process always present problems for the researcher. Some factors of production depreciate, while others appreciate in real value. Also, some supply a fairly constant flow of services during their life span, while others present a flow of services which varies with age. Accurate input measurement requires detailed analysis of each input's contribution individually on a fairly disaggregated basis.[4]

Only gross approximations were used here to transform stock into flow variables, since data were not available to permit a more elaborate analysis. Charges at rental rates were made against the stock value of the input, by using conversion ratios "chosen to reflect the opportunity costs of capital in off-farm investment of similar nature" (Drummond, 1972, p. 167). Drummond's conversion ratios, developed for Brazilian farmers somewhat similar to the ones in this study was used here. Actual values of the ratios were: 6 percent for livestock, 4 percent for permanent structures, 12 percent for machinery and equipment, and 100 percent for operating expenses in general.

Output Variable

Total gross output is defined as the sum of crop and livestock sales, family privileges, hired labor privileges, changes in the value of the livestock inventory, value of abnormal livestock losses, value of rent payment made in kind, minus the value of livestock purchases.

Most items included in this working definition are self-explanatory. However, two of them deserve special attention: (a) the value of livestock purchases and (b) the value of abnormal

---

[4]A detailed treatment of the theory of input measurements and the transformation from stock into flows can be found in Yotopoulos (1967).

losses. The value of livestock purchases positively affects livestock output, and had to be subtracted from output since it was not the result of the farmer's production. Abnormal livestock losses was defined as the difference between observed livestock losses and a statistically determined level of normal livestock losses.[5] When the level of losses is significantly large (i.e. when abnormal losses occur) the observed changes in livestock inventory and total gross output are biased downward. Therefore, the value of abnormal losses was added to the other production items as a corrective factor.

Estimation

On the basis of the theoretical justification discussed earlier single equation models were set up. Several models were initially specified, starting from very disaggregated models to more aggregated ones. The OLS statistical technique was used to fit the linearized form of the model to the sample data.[6] More disaggregated models did not fit the data well. This may have resulted from lack of good measures of some items such as family labor, expenses on non-mechanized equipment, and/or from specification errors. Two models were selected. Model I includes land, labor, working assets and operating expenses as independent variables. In Model II the two capital variables are combined. The results of these two models are presented in the next section.

---

[5] For a detailed explanation of how abnormal losses was computed see Reichert, (1972), Appendix B.

[6] OSU-Economic Regression Program, by Dr. John Cunnyngham, and computer facilities were utilized for this purpose.

Empirical Results and Analysis

The Three Types of Farms - A Comparison

Beef cattle farms, mechanized wheat farms and "mixed" farms, as defined in this study, are considerably different when compared on the basis of the arithmetic mean values of selected variables.

In terms of size (measured in hectares) cattle farms are the largest farms with an average of 539.26 ha of operated land. The next largest farms are mechanized wheat farms with 189.37 ha, and the smallest farms are the mixed farms with an average of 145.04 ha (Table 1.).

With respect to land use, the data show that cattle farmers cultivate only 2 percent of their operated land, 89 percent is used as natural pasture, and 9 percent is "other land". Considering that cultivated land includes improved pasture and that these farmers usually devote some land to crop production, it must be inferred that these cattle farmers have an insignificant proportion of their land in improved pasture.

On mixed farms 61 percent of the operated land is in pasture, 31 percent is cultivated land and 8 percent is other land. On wheat farms 55 percent of the operated land is cultivated, 40 percent is used for pasture, and 5 percent is other land. This large proportion of the wheat farms land in natural pasture is a

TABLE 1.--Input Use and Output Level by Farm Type - Sample Arithmetic Means and Coefficient of Variation[1]

	Cattle Farms			Mixed Farms			Wheat Farms		
	Unit	Percent	C.V.	Unit	Percent	C.V.	Unit	Percent	C.V.
LAND:	(Ha)			(Ha)			(Ha)		
Cultivated	12.35	2	226	44.60	31	190	104.70	55	162
Natural Pasture	476.69	89	150	89.05	61	126	74.73	40	231
Other Land	50.22	9	219	11.39	8	149	9.94	5	352
Operated	539.26	100	151	145.04	100	96	189.37	100	172
LABOR:	(m.e.)			(m.e.)			(m.e.)		
Family Labor	1.43	56	66	1.57	26	84	1.65	32	61
Hired Labor	1.11	44	140	4.43	74	152	3.56	68	108
Utilized	2.54	100	59	6.00	100	114	5.21	100	73
CAPITAL:	(Cr$)			(Cr$)			(Cr$)		
Buildings	33,274.78	24	178	39,415.00	21	167	31,498.57	15	140
Mach. & Equipment	9,153.09	7	142	86,951.03	46	146	125,809.12	60	67
Livestock	95,801.49	69	121	62,391.20	33	229	51,066.12	25	163
		100			100			100	
W. Assets	138,229.36	(96)	123	188,757.23	(82)	145	208,373.81	(77)	74
Crop Expenses	412.87	8	319	16,899.80	40	149	32,713.05	54	92
Mach. Expenses	1,297.51	26	183	20,576.72	49	147	25,037.24	41	100
Livestock Expenses	1,655.07	33	157	1,545.47	4	230	1,353.67	2	172
General Expenses	1,639.10	33	186	2,756.88	7	184	1,707.48	3	139
		100			100			100	
O. Expenses	5,004.55	(4)	161	41,778.87	(18)	139	60,811.44	(23)	85
Total Capital	143,233.91	100	(123)	230,536.10	(100)	138	269,185.25	(100)	70
OUTPUT	23,429.42		114	122,753.67		156	162,762.12		78

[1]Note: $C.V. = \frac{s.d.}{\bar{x}}$ where s.d. is the standard deviation and $\bar{x}$ the arithmetic mean of each variable.

bit surprising. It seems to indicate that wheat farmers have considerable flexibility in use of the land input for wheat production.

Differences are also noticeable among farm types with respect to labor use. The mean amount (in man-equivalents) of labor used on cattle farms is 2.54 m.e., while mixed farms and wheat farms use 6.00 m.e. and 5.21 m.e., respectively. Cattle farmers rely mostly on family labor (56 percent of the total amount used), whereas mixed farmers and wheat farms rely on family labor for only 26 and 32 percent of their total labor.

The most important differences among these farm types is in their capital structure, particularly between cattle and wheat farms. The average value of investments, excluding the value of land, on wheat farms is almost twice as large as on cattle farms.

The form of the capital investment also varied considerably; cattle farms have 96 percent of their capital in working assets (mostly in the form of livestock and buildings), mixed farms have 82 percent in working assets, and wheat farms have only 77 percent of the total capital as working assets.

These figures indicate that wheat farmers concentrate heavily on mechanized equipment in both absolute and relative terms with respect to the other farm types. Machinery and equipment account for 60 percent of the wheat farms' working assets. Moreover, 95 percent of the operating expense is accounted for by machinery (41 percent) and crops (54 percent) expenses.

Table 1 also contains the coefficient of variation (C.V.) of each variable considered. The coefficient of variation is larger than 100 percent for most of the variables. Family labor is the only variable with a C.V. consistently below 100 percent for all three types of farms. Hired labor's C.V. is also less than 100 percent for mixed and wheat farms. This characteristic (low variability) of the labor input seems to indicate that farming is primarily a family business in this region, even on the mechanized wheat farms.

Another important characteristic which differentiates the farm types is land tenure. Cattle farmers are mostly owner-operators (Table 2). Rather than rent land from others, they often rent part of their land to others. Wheat farmers usually rent in at least part of their land. Approximately 33 percent of them rent all the land they operate, and only 5 percent own all the land they operate. Again, mixed farms constitute an intermediate stage between cattle and wheat farms. Differences in land tenure partially explain the observed differences in capital structure and land use.

There are important differences among these farm types, as shown by this preliminary analysis. These differences should be borne in mind as they help explain some of the empirical results discussed in the following sections.

TABLE 2.--Frequency Distribution of the Farms in the Sample According to Land Tenure and Farm Type

Tenure Class[1]	Frequency					
	Cattle		Mixed		Wheat	
	No.	Percent	No.	Percent	No.	Percent
A	15	23	7	12	2	5
B	3	5	7	12	17	40
C	41	61	21	35	2	5
D	0	0	17	28	14	33
E	8	11	8	13	7	17
Sample	67	100	60	100	42	100

A = Does not rent land to or from others

B = Operates own land and rents from others (may rent more than 50 percent), but does not rent to others

C = Operates part of his land and rents the rest to others

D = Rents all the area operated

E = Other systems

Empirical Estimates

Several different models were fitted to the data. Two were selected for the comparative analysis. Criteria used in selecting these two models were (a) statistical best fit indicators and (b) usefulness for economic analysis.

Some of the statistical estimates are similar for all farm types and models. For example, all three functions present an adjusted coefficient of multiple determination (R^2 -adj.) varying from 0.80 to 0.86, and a high level of significance of the regression estimate according to the Analysis of Variance test. Other similarities among the estimates are related to returns to scale and multicollinearity.

Returns to Scale

The sum of the Cobb-Douglas production elasticity estimates is usually taken as a measure of returns to scale. In this sense the results presented in Table 3 indicate constant returns to scale in Southern Brazil. The sum of the production elasticities (for each farm type) is not significantly different from unity, at the 1 percent probability level.[7] Similar results have been found for several other countries (Heady and Dillion, 1961; Yotopoulos, 1967).

---

[7]These results must be interpreted cautiously, because management was not specified. Attempts made to avoid specification bias by specifying management in other research work have not been successful due to a lack of measurement of the effect of management on production (Sorenson, 1968).

TABLE 3.--Characteristics of the Empirical Production Functions, by Farm Type

Model and Characteristic	Farm Type		
	Cattle	Mixed	Wheat
Model I:			
R^2 (adj)	0.8183	0.8593	0.8588
F - ratio[a]	75.3010	91.0864	63.3334
$S^2_{y.x}$	0.0434	0.2856	0.1457
d.f.	62	55	37
Return to Scale[b]	1.0600	1.0318	1.0826
(S.D.)	(0.0970)	(0.1048)	(0.0903)
Model II:			
R^2 (adj)	0.7987	0.8641	0.8570
F - ratio[a]	85.1348	126.0580	82.9344
$S^2_{y.x}$	0.0495	0.2807	0.1466
d.f.	63	56	38
Return to Scale[b]	1.0126	1.0316	1.0951
(S.D.)	(0.1012)	(0.1021)	(0.0755)

[a]All F - values are statistically significant at the 1 percent level.

[b]No return to scale is significantly different from unity, at the 1 percent probability level.

Specification Bias

Since management was not specified the estimated production elasticities (and hence, the returns to scale) are subject to specification bias. The direction of the bias depends on the association between the specified inputs and management. "There are a priori theoretical reasons to believe that constant returns to scale must prevail if all inputs are included. Indeed, the exclusion of the management factor would lead to an underestimation of the returns to scale, if we assume that the omitted factor varies less than proportionately with changes in the included factors over the range of the sample observations" (Yotopoulos, 1967; p. 182).

The implication of excluding management in a Cobb-Douglas production function analysis is that the inferences must be based on the average firm. It is implicitly assumed thereby that the estimation of the function is based on the average level of management in the sample (Mundlak, 1961).

Multicollinearity

Whenever explanatory variables are correlated with each other in regression analysis multicollinearity is present. "Of particular interest are cases of high degree of multicollinearity, which arise whenever one explanatory variable is highly correlated with another explanatory variable or with a linear combination of other explanatory variables" (Kmenta, 1971; p. 380). The author points out that the problem "is a question of degree and not of kind."

The most serious consequence of a high degree of multicollinearity is the large value of the standard deviations of the regression coefficients. This implies that the probability of making a type II error is increased considerably. Or alternatively, the t-test of the individual regression coefficients fails to reject the null hypothesis (when it should) more frequently than would be the case if no serious multicollinearity problem existed.

The simple correlation coefficients between pairs of explanatory variables are usually considered indicators of multicollinearity. In this study, high levels of correlation between working assets and operating expenses result in a multicollinearity problem in Model I (Table 4). Model II, in which these two variables are aggregated into total capital, aims at reducing the degree multicollinearity. But total capital and labor are also highly correlated in both the mixed farms and wheat farms samples in Model II.

The empirical results reveal that the multicollinearity problem did not affect the test of the production elasticities very much, but variances of the marginal value products of the inputs were seriously affected. Consequently, the confidence intervals initially placed on the MVP were seriously overestimated.

TABLE 4.--Matrix of the Correlation Coefficients by Farm Type in the Sample

Variable and Farm Type	Variable					
	X_1	X_5	X_9	X_{27}	X_{30}	X_{41}
X_1 = Output						
Cattle	1.00					
Mixed	1.00					
Wheat	1.00					
X_5 = Land						
Cattle	.55	1.00				
Mixed	.10	1.00				
Wheat	.60	1.00				
X_9 = Labor						
Cattle	.52	.31	1.00			
Mixed	.80	.17	1.00			
Wheat	.70	.44	1.00			
X_{27} = Working Assets						
Cattle	.90	.57	.48	1.00		
Mixed	.89	.25	.79	1.00		
Wheat	.87	.59	.77	1.00		
X_{30} = Operating Expenses						
Cattle	.79	.48	.49	.87	1.00	
Mixed	.90	.06	.76	.87	1.00	
Wheat	.87	.40	.64	.79	1.00	
X_{41} = Total Capital						
Cattle	.89	.55	.49	.98	.94	1.00
Mixed	.93	.13	.80	.95	.98	1.00
Wheat	.91	.47	.70	.88	.98	1.00

Beef Cattle Production Function

The traditional factors of production, land, labor, and capital explain about 82 percent of the variation in beef cattle production (Table 5). The elasticity of production of working assets is 0.81, which denotes a very high response in production to changes in this input. The elasticity of production of operating expenses, on the other hand, is not significantly different from zero, even at the 25 percent level of probability. In addition, this elasticity carries a negative rather than the expected positive sign.

The elasticity of production of land and labor are significantly different from zero at the 25 and 5 percent probability levels, respectively. But they indicate that production response is much smaller to changes in these inputs than to changes in working assets.

Working assets explain most of the output variation in both models. Little is explained by the other inputs. Rao and Miller (1971; p. 40) point out that this type of estimation problem frequently occurs in empirical research when the dependent variable is somehow functionally related to an independent variable in relatively fixed proportion. They also point out that "Whether a variable is truly superfluous" (as operating expenses seem to be in this case) "or is a consequence of the presence of a dominant variable" cannot be determined on *a priori* grounds. In the present case, two factors seem to explain the dominant effect of working

TABLE 5.--Regression Coefficients, Average and Marginal Value Products, Geometric Means and R^2 (adj.), as Estimated by Models I and II, for Cattle Farms

Model, Input and Output	Regression Coefficient (S.D.)	Average Value Product	Marginal Value Product	Goemetric Mean
MODEL I ($\bar{R}^2$ = 0.82)				
Intercept	0.9656[a] (0.2107)	-	-	-
Land (ha)	0.0448[e] (0.0569)	53.28	(2.39)	246.00
Labor (m.e.)	0.2007[b] (0.1072)	6,182.54	1,240.84	2.12
W. Assets (Cr$)	0.8148[a] (0.1116)	2.88	2.35	4,544.00
O. Expenses (Cr$)	-0.0003 (0.0828)	6.56	(-0.00)	1,997.00
MODEL II ($\bar{R}^2$ = 0.80).				
Intercept	1.0337[a] (0.2185)	-	-	-
Land (ha)	0.0769[d] (0.0598)	6,182.54	(4.10)	2.12
Labor (m.e.)	0.1969[b] (0.1138)	2.88	1,217.34	4,544.00
Capital (Cr$)	0.7388[a] (0.0687)	1.90	1.41	6,890.00
OUTPUT (Cr$)	-	-	-	13,107.00

Notes
(1) a, b, c, d, and e indicate statistical significance at 1, 5, 10, 12.5, and 25 percent probability levels, respectively.
(2) $\bar{R}^2$ (adj.) = adjusted R-squared.
(3) All the MVPs were computed at the geometric mean values of the inputs and output. MVPs in parentheses were computed with production elasticities nonsignificantly different from zero at the 10 percent probability level.

assets on output: (a) the low level of technology and (b) the extensive use of land in cattle production. Under traditional methods of production, it is logical to expect production to depend mostly on the animal stock. As observed previously, 96 percent of the capital investment on these farms (other than that invested in land) is in working assets, and livestock accounts for 69 percent of this capital item.

In terms of resource allocation, the MVPs (Table 5) indicate that land and operating expenses are being used to (or near) the point of zero marginal value product. Unless the opportunity costs of land is zero, economic inefficiency is evident. Decreasing the amount of land can be expected to increase total profit, *ceteris paribus*.

The estimate of MVP of labor is Cr $1,241 per man-equivalent. The average regional wage rate was Cr $1,725 per m.e. at the survey time, according to the research team. This result also suggests too much labor is being used by cattle farmers for existing size of beef herd, in spite of the small absolute amount of labor employed (2.12 m.e. on the average) per farm.[8]

---

[8]Unfortunately a statistical test of the equality between the MVP and the market price of each input was precluded by the fact that input prices were not collected directly from those interviewed. Average regional input prices from secondary sources were used by the researchers whenver necessary. An alternative method was tried here to perform this test. Confidence intervals were placed on the MVPs so that they could be compared to the average input price. As it turned out, however, these C.I. (even at the 90 percent level for the coefficient of confidence) were not reliable. High multicollinearity affecting the variance of the MVPs seems to have been the cause of the serious overestimation of the confidence intervals.

The estimate of the MVP of working assets is 2.35 cruzeiros worth of output per additional cruzeiro used in the production process (Model I). If total capital is considered (Model II), the general conclusions still hold with respect to the overall inefficient use of resources, but the return per additional cruzeiro invested on capital items is reduced to 1.41. This result still indicates that there is a gross margin of 41 percent on capital investment.

Aggregation of the capital input variables slightly affects the elasticity of production of land. It increases from 0.04 to 0.08 and becomes significantly different from zero at the 10 percent probability level. No major change occurs on the MVP of land.

Mixed Farms Production Function

Land, labor and capital changes explain about 86 percent of the variation in output in this case. The production elasticities of all inputs but land are significantly different from zero at the 5 percent probability level (Table 6). Land's production elasticity, besides being non-significant, carries a negative sign. A plausible explanation for the negative sign may be in the composition of the mixed farms group. Since this group includes farms with intensive land use as well as those with very extensive land use, the net composite effect of changes in land operated may

TABLE 6.--Regression Coefficients, Average and Marginal Value Products, Geometric Means and $\bar{R}^2$ (adj.), as Estimated by Models I and II for Mixed Farms

Model, Input and Output	Regression Coefficient (S.D.)	Average Value Product	Marginal Value Product	Geometric Mean
MODEL I: ($\bar{R}^2$ = 0.86)				
Intercept	1.2109[a] (0.3467)	-	-	-
Land (ha)	-0.0758 (0.0856)	384.25	(-29.09)	89.10
Labor (m.e.)	0.2512[b] (0.1315)	9,743.02	2,447.45	3.51
W. Assets (Cr$)	0.4775[a] (0.1482)	5.18	2.47	6,607.00
O. Expenses (Cr$)	0.3789[a] (0.0908)	3.54	1.34	9,661.00
MODEL II: $\bar{R}^2$ = 0.86				
Intercept	0.9275[a] (0.3363)	-	-	-
Land (ha)	-0.0532 (0.0779)	384.25	(-20.42)	3.51
Labor (m.e.)	0.2481[b] (0.1287)	9,743.02	2,417.24	6,607.00
Capital (Cr$)	0.8367[a] (0.0825)	1.82	1.52	18,763.00
OUTPUT	-	-	-	34,198.00

Notes: (1) a, b, c, d, and e indicate statistical significance at 1, 5, 10, 12.5, and 25 percent probability levels, respectively.
(2) $\bar{R}^2$ (adj.) = adjusted R-squared.
(3) All the MVPs were computed at the geometric mean values of the inputs and output. MVPs in parentheses were computed with production elasticities nonsignificantly different from zero at the 10 percent probability level.

well be neutral and carry the negative sign. Increases in operated land by some farmers in the sample may have occurred by renting land from other farmers in the same group thereby neutralizing the average effect of changes in the land input. This result is more likely to occur in heterogeneous groups of farms (such as the mixed farms), but does not have to be true for all groups of diversified farms. Positive and significant land production elasticities have been found for production functions of diversified farming areas (Drummond, 1972; p. 72).

The MVPs again indicate the presence of economic inefficiences in resource allocation. Land is being used in much larger proportion than would be most profitable (Table 6). Labor's MVP (Cr $2,477.45) is fairly high as compared to the regional average wage rate, indicating room for higher levels of employment in mixed farming. The MVP of capital variables also indicate underutilization of capital on these farms. A gross margin of return on investment of about 34 percent on operating expenses and 147 percent on working assets investment was found (Model I). As an aggregate (Model II) the capital input offers a return of 52 percent at the margin.

In short, resources are not being allocated in the most efficient way considering the norms of neoclassical marginal productivity theory. The results suggest that this group of farmers can increase profits by releasing land for rent, hiring more labor, and increasing the use of capital.

Wheat Farms Production Function

Variations in the specified inputs explain 86 percent of the output produced by mechanized wheat farms. The production elasticity of labor in this farm type is not significantly different from zero at the 5 percent probability level, even though it carries the expected positive sign (Table 7). When working assets and operating expenses are aggregated into total capital (Model II), labor's production elasticity increases from 0.05 to 0.10 and becomes significantly different from zero at the 25 percent probability level. Hence, the aggregation of these two capital variables (which are highly correlated) improves the estimate and the significance level of labor's production elasticity. Better measurement of the flow of services from the capital variables would likely improve the estimates of all elasticity coefficients. Further improvement could be obtained by accounting for land and labor quality, if measures of quality were available.

Land and capital inputs present highly significant elasticities of production, reflecting an intensive use of both land and capital. Production elasticity of operating expenses is particularly high (0.55). High response to changes in operating expenses associated with intensive use of land is consistent with the fact that most wheat farmers rent part or all of the land they operate (Table 7).

The MVP of labor as measured by Model I does not inspire much

TABLE 7.--Regression Coefficients, Average and Marginal Value Products Geometric Means, and R^2 (adj.), as Estimated by Models I and II for Wheat Farms

Model, R^2 (adj.) Input and Output	Regression Coefficient (S.D.)	Average Value Product	Marginal Value Product	Geometric Mean
MODEL I. $R^2 = 0.82$				
Intercept	0.7471[b] (0.4137)	-	-	-
Land (ha)	0.1235[a] (0.0498)	1,564.00	193.26	74.96
Labor (m.e.)	0.0491 (0.1119)	28,750.00	(1,413.01)	4.08
W. Assets (Cr$)	0.3599[a] (0.1435)	7.86	2.83	14,928.00
O. Expenses (Cr$)	0.5501[a] (0.1033)	2.62	1.44	44,751.00
MODEL II. $R^2 = 0.80$				
Intercept	0.6331[c] (0.4116)	-	-	-
Land (ha)	0.1393[a] (0.0463)	1,564.00	217.98	74.96
Labor (m.e.)	0.0959[d] (0.1018)	28,750.00	(2,759.83)	4.08
Capital (Cr$)	0.8599[a]	1.92	1.65	61,249.00
OUTPUT	-	-	-	117,300.00

Notes: (1) a, b, c, d, and e indicate statistical significance at the 1, 5, 10, 12.5 and 25 percent probability levels, respectively.
(2) $\bar{R}^2$ (adj.) = adjusted R-squared.
(3) All the MVPs were computed at the geometric mean values of the inputs and output. MVPs in parentheses were computed with production elasticities nonsignificantly different from zero at the 10 percent probability level.

confidence that labor's production elasticity is not significantly different from zero, even at the 25 percent level of probability. However, in Model II it becomes significant at that level, thus seeming to indicate that there is some response in wheat production to additional labor. The MVP is below the regional average wage rate as estimated by Model I and above that average when estimated by Model II. It seems reasonable to argue, however, that wheat production requires higher quality labor given the relatively high level of mechanization. Hence, actual wage rates may be larger or at least near the MVP estimated by Model II. Therefore, wheat farmers are hiring about the right quantity of labor to maximize economically efficient use of this input.

Underinvestment in land is evidenced by comparing the MVP of land to its opportunity cost. The opportunity cost of land, as measured by the interest on capital invested, is Cr $12.48 per hectare in Rio Grande do Sul (Noskosky, 1971; p. 89). As the MVP of land is Cr $193.00 (Model I), considerable increase in profits would be obtained by renting additional land, if the opportunity cost quoted actually reflects the land rental market.

Capital is also being used at less than the optimum levels in wheat production. Working assets and operating expenses yield returns of 2.83 and 1.44 <u>cruzeiros</u> worth of output, respectively, per additional <u>cruzeiro</u> used in wheat production (Model I).

A marginal return of 65 percent exists when considering total capital in the farm business (Table 7, Model II).

In summary, it is quite clear that capital and land are highly productive while labor is being used to the optimal point in wheat production. It should be emphasized that this farm type is the only one which presents a highly productive land input. This is an exceptional case in a developing country such as Brazil where land is usually very extensively used.

Comparative Analysis

The foregoing analysis of the individual production functions shows that resources are not being allocated in the most profitable manner within each farm type. These farms are all located in a fairly homogeneous region. Moreover, there is reason to believe that the market imperfections which may exist are not strong enough to impede resource mobility within the region. Therefore, it becomes imperative to look at the allocation of resources among these farm types and attempt to identify possible future patterns of resource use.

The preliminary description of the three farm types has shown that they differ significantly in many aspects.

The Chow test confirms this result. It indicates that the null hypothesis stating strict equality among all three production functions must be rejected at the 5 percent or lower probability level (Table 8). In general, the results indicate that studying

TABLE 8.--Comparison of the Production Functions Between Farm Types (The Chow Test)

Farm Types	Model I		Model II	
	F-estimate	d.f.	F-estimate	d.f.
Cattle vs. Wheat	9.35[a]	(5;99)	3.44[b]	(4;101)
Cattle vs. Mixed	3.14[b]	(5;122)	0.71	(4;124)
Wheat vs. Mixed	1.37	(5;92)	1.62	(4;94)
All three types	4.35[a]	(8;161)	2.07[b]	(6;163)

Note: a,b and c indicate statistical significance at the 1, 5, and 10 percent probability levels, respecitvely.

individual farm types leads to better quality estimates than pooling different farm types together for the purpose of estimating production functions in the region.

The sample results indicate that the hypothesized equality between cattle and wheat farm production functions must be rejected at the 5 percent probability level (Models I and II). Model I yields this same result when cattle and mixed farm production functions are compared. However, the sample data do not provide evidence for rejecting the same hypothesis regarding cattle and mixed farms when Model II is fitted.

Neither Model I nor Model II lead to the rejection of null hypothesis (at the same level of significance) when wheat and mixed farm production functions are compared for equality.

In order to perform a more detailed analysis of the differences between farm types, the Chow test was also used to compare individual production elasticities of different production functions. Only Model I was used for this purpose and the results are presented in Table 9.

TABLE 9.--Estimates of the F-Statistic Used to Test the Difference Between Elasticities of Production of Individual Inputs - Model I

Input	Cattle vs. Mixed	Mixed vs. Wheat	Cattle vs. Wheat
Intercept	0.71	2.35	0.62
Land	2.48	16.19[a]	1.94
Labor	0.14	4.86[b]	1.87
Working Assets	5.30[b]	1.10	13.66[a]
Op. Expenses	13.03[a]	5.01[b]	37.13[a]
d.f.	(1;122)	(1;92)	(1;99)

Note: a,b and c indicate statistical significance at the 1, 5, and 10 percent probability levels, respectively.

Statistically significant differences are revealed by the Chow test between the elasticities of production of capital when cattle and mixed (as well as cattle and wheat) farms are compared. When mixed and wheat farms are compared, the null hypothesis of equal production elasticities for labor, land and operating expenses must be rejected at the 5 percent level of probability. Only working assets presents a non-significant statistical difference in this case.

With respect to the intercept, when any two farm types are compared the sample data do not lead to the rejection of equality hypothesis at the 5 percent probability level between the intercepts of the functions.

The overall results of this comparative analysis show that a general state of resource misallocation prevails in the region. Economic efficiency in the region could be substantially increased by simply reallocating the existing resources. The excess of labor and land currently being used by cattle farmers would increase efficiency if shifted to mixed and wheat farms. Mixed farms could also rent additional land to wheat farmers thereby contributing to an increase in economic efficiency. However, the results suggest that capital is a limiting resource. There are high returns to capital investment in the region, principally in working assets.[9] This result throws suspicion of the efficiency of the capital market in responding to a high demand for capital.[10] Rao (1970, p. 128) found that "farm types representing small scale agriculture, appear to be facing credit rationing" whereas large mechanized crop farmers "appear to be relatively free from capital constraints." Capital rationing may well be the case here even though none of the three farm types can be considered small agriculture in absolute terms.

---

[9]This high level of productivity of capital is evidence of favorable conditions for capital formation at the farm level regardless of farm type.

[10]It may also be a case of self-rationing caused by risks and uncertainties.

Reallocation of resources can also be attained through economic policy. If the price subsidy for wheat were eliminated, considerable changes would take place in the region. Heavy mechanized equipment and fertilizer currently used in wheat production would likely be shifted to mixed farms and cattle production.[11] Consequently, higher productivity levels would be attained by these two farm types, improving their competitive position. However, as long as the subsidy policy is maintained, it is likely that resources will shift from cattle production to mixed and wheat farms which offer higher returns.[12]

Wheat and soybeans (which are complementary products), and beef are under increasing world demand. Hence, the relative prices of these products may not change significantly in the short run. Therefore, the competitive position of the beef cattle business in Southern Brazil will continue to depend on major changes in the technology of beef cattle production.

---

[11] Some of the machinery and equipment used in wheat production cannot be adapted to the production of other crops (and livestock) in the short run. Others cannot be adapted (and hence transferred) at all. Therefore, such shift to mixed and livestock would be a slow process.

[12] Engler (1971) shows that the cattle farmers best economic alternative in this region is to move beef cattle production to a combination of wheat and soybean, unless beef prices and production technology increase substantially.

SUMMARY AND CONCLUSIONS

Summary

This is a study of the economics of resource allocation in Southern Brazil. The specific objectives pursued are:

(1) To determine possible differences between production functions of three different types of farms in the region: beef cattle, mecahnized wheat farms and "mixed" farms.

(2) To determine differences in productivity levels, as measured by the production function estimates, as a means to appraise resource allocative efficiency.

(3) To determine possible effects of the current price policy on the pattern of resource use in the region and the potential for capital formation at the farm level.

It is also hoped that the current dynamic move away from beef cattle and toward wheat production in this region can be at least partially evaluated by this analysis.

The procedure involved estimation of Cobb-Douglas production function using cross-sectional data. A modified form of the Zellner et al. (1966) stochastic model was used. This model's basic assumption is that the entrepreneur's objective is to maximize his profit function.

The data utilized for empirical estimation were collected by directly interviewing a sample of 169 farmers in Sao Borja, Rio Grande do Sul, in 1969-70. For this research the original sample was subdivided into three groups of farms based on the relative importance of beef cattle and wheat production in the farm business. There are

67 cattle farms, 42 wheat farms and 60 mixed farms in the sample.

Conclusions

Significant differences were found between the three farm types. These differences are reflected by the shape of the production functions and by differences among the elasticities of production of individual inputs. The main factors explaining such differences in the production process are the capital structure of each farm type, technological level and market incentives.

Economic inefficiency, as measured by disequality between the MVP and the opportunity cost of the inputs, was observed in all farm types. Cattle farms have relatively low average and marginal productivities as compared to the mixed and wheat farms. Wheat farms have the highest productivity levels. That the mixed farms group has an intermediate level of average and marginal productivity supports the hypothesis that mixed farming is a transitional stage between the other two farm types--a stage in the process of changing from traditional cattle production into wheat production.

Cattle farmers are using land, labor and operating expenses very extensively. The MVPs of land and operating expenses are practically zero, and the MVP of labor is very low. These farmers are usually owner-operators and rely mostly on family labor. They can increase profits by increasing the proportion of working assets particularly in the form of cattle, to other inputs. The production elasticity of working assets (and high MVP of this input) are evidence of such potential gains.

Mixed farms, on the other hand, use too little capital and labor, while land is being used beyond the most profitable point. This farm group is very heterogeneous, as it includes both intensive as well as extensive users of land and other inputs. Results indicate that these farms are potential users of additional labor. They are the only ones in the region with underinvestment in labor.

Wheat farmers have attained the highest productivity levels in the region. There is evidence of adequate use of labor by these farmers with underinvestment in land and capital. This farm type presents a rare case of high productivity of land. The explanation for high land productivity appears to be the use of modern inputs (including mechanized equipment) and possibly a better quality of land. Intensive use of land is also explained by the fact that wheat farmers usually rent most of their land from others.

Looking at individual inputs, the most productive one is capital. Working assets represent the only input which has consistently very high MVP as well as AVP across all farm types. This result is strong evidence of generally favorable conditions for capital formation at the farm level irrespective of farm types. Increases in capital formation would certainly increase the MVP of other inputs as well.

This general high return to capital investment in the region throws suspision on the efficiency of the capital market in responding to a high demand for capital. Evidence of imperfections in the capital market have been pointed out by Rao (1970, p. 128) who stated that large mechanized crop farmers "appear to be relatively free from capital constraints while all other types representing small agriculture appear to be facing credit rationing." In any event, a shortage of capital seems evident in face of current demand.

Agricultural production in this region is very responsive to use of capital, under the current "state of the arts." A well formulated credit policy would result in substantial increases in agricultural production.

A comparative analysis shows that cattle farmers are in a disadvantageous position, because of the current wheat price subsidy policy and the level of technology. Productivity differences indicate that economic efficiency will be increased if resources are attracted out of less productive activities into more productive ones. Therefore, it is logical to expect resources to be transferred from beef cattle production into mixed farming and wheat production, respectively, under the present situation. If the wheat price subsidy is eliminated (an unlikely occurance in the short run), it is conceivable that the MVP of resources used in wheat production will decrease making this transfer less attractive. It may even result in reverting the process, transferring modern inputs currently used in wheat production to mixed farming and cattle production hence increasing their productivity levels.

Given that beef, wheat and soybeans are similarly under increasing demand in the world market, it is very unlikely that their relative prices will change significantly in the near future. Therefore, the competitive position of the beef cattle business in Southern Brazil will continue to depend on substantial changes in production technology.

BIBLIOGRAPHY

Adams, Dale W. 1970. "Agricultural Development Strategies in Brazil 1950-70." The Ohio State University, Columbus, Ohio. (Mimeo.), 37 pp.

Baer, Werner. 1972. "The Brazilian Economic Miracle." A Public Lecture presented at The Ohio State University, Columbus, Ohio. Office of International Programs.

Baklanoff, Eric N. 1971. "Brazilian Development and the International Economy," IN, Modern Brazil, edited by John Saunders. Gainesville, University of Florida Press, 350 pp.

Carter, H. O. and H. O. Hartley. 1958. A Variance Formula for Marginal Productivity Estimates Using the Cobb-Douglas Function. Econometrica 26 ( ) 306-313.

Chow, Gregory C. 1960. Tests of Equality Between Sets of Coefficients in Two Linear Regressions. Econometrica 28 (3) 591-605.

Cunnyngham, Jon. 1969. "OSU/Econ Regression Program Operating Instructions." The Ohio State University, Columbus, Ohio (Mimeo.) 22 pp.

De Janvry, Alain, 1972. "The Generalized Power Production Function" Journal of Agricultural Economics, 54 (2): 234-237.

Drummond, Harold Evan. 1972. "An Economic Analysis of the Farm Enterprise Diversification and Associated Factors in Two Regions of Minas Gerais-Brazil." Purdue University (Unpublished Ph.D. Dissertation), 189 pp.

Engler, Joaquim Jose de Camargo, 1971. Alternative Enterprise Combinations under Various Price Policies on Wheat and Cattle Farms in Southern Brazil. The Ohio State University - DAERS - (Unpublished Ph.D. Dissertation), 221 pp.

Griliches, Zvi, 1957. "Specification Bias in Estimation of Production Functions." Journal of Farm Economics, 39: 8-20.

Heady, Earl O. and John L. Dillon, 1961. Agricultural Productions Functions. Ames, Iowa, Iowa State University Press. 667 pp.

Hill, Lowell and Takashi Takayama, 1971. "Statistical Tests for Comparing Means Variances, and Regression Coefficients." University of Illinois, Urbana-Champaign.

Hogg, Robert V. and Allen T. Craig, 1972. "Introduction to Mathematical Statistics." Third Ed., New York, The MacMillan Company. 415 pp.

Kmenta, Jan. 1971. Elements of Econometrics. New York, The MacMillan Company, 655 pp.

Mundlak, Y. 1961. Empirical Production Functions Free of Management Bias. Journal of Farm Economics, 43: 44-56.

Noskoski, Carlos. 1971. Analise Economica do Uso de Corretivos na Cultura do Trigo, Safra 1969 - Ibiruba - RS. UFRS - FCE - IEPE - Porto Alegre, (Tese de M.S.) 91 pp.

Rao, Bodepudi Presada. 1970. The Economics of Agricultural Credit - Use in Southern Brazil. The Ohio State University - DAERS - (Unpublished Ph.D. Dissertation), 161 pp.

Rao, P. and R. LeRoy Miller, 1971. "Applied Econometrics" Belmont, California, Wadsworth Pub. Company, Inc., 235 pp.

Rask, Norman and Richard L. Meyer. 1972. Analysis of Capital Formation and Technological Innovation at the Farm Level in LDC's. The Ohio State University - DAERS - Agr. Econ. Res. Series. 47 pp.

Reichert, Allen. 1972. Capital Formation Project. Summary data Set: Coding Format, Variable Description and Source Location. The Ohio State University - DAERS - 36 pp.

Richter, Humberto Vendelino, 1971. "Analise Economica do Sistema Produtivo e Uso de Nova Tecnologia na Exploracao de Gado de Corte - Bage-Rio Grande do Sul." Porto Alegre (IEPE-UFRGS), 142 pp.

Schuh, G. Edward. 1970. Research on Agricultural Development in Brazil. New York, The Agricultural Development Council, Inc. 302 pp.

Sorenson, Donal M. 1968. Capital Productivity and Management Performance in Small Farm Agriculture in Southern Brazil. The Ohio State University - DAERS - (Unpublished Ph.D. Dissertation), 164 pp.

Souza, Eli de Moraes, et al. 1972. "Formacao de Capital e Mudancas Tecnologicas ao Nivel de empresas Rurais - Sao Borja - RS." Porto Alegre UFRS (IEPE), Estudos e Trabalhos Mimiografados No. 20, 51 pp.

Steitieh, Akram Justafa. 1971. Input Productivity and Productivity Change of the Crop Enterprise in Southern Brazil. The Ohio State University (Unpublished Ph.D. Dissertation), 103 pp.

Timmer, C. Peter, 1970. "On Measuring Technical Efficiency" Stanford University, Food Research Institute Studies, Vol. IX, No. 2, pp. 99-171.

Yotopoulos, Pan A. 1967. "Allocative Efficiency in Economic Development." Athens: CPER, 313 pp.

Zellner, A., J. Kmenta and J. Dre/e. 1966. Specification and Estimation of Cobb-Douglas Production Function Models. Econometrica 34 (4): 784-795.